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CRYOGENIC MATERIALS DATA HANDBOOK

PROGRESS REPORT

AIR FORCE MATERIALS LABORATORY
RESEARCH AND TECHNOLOGY DIVISION
AIR FORCE SYSTEMS COMMAND
WRIGHT-PATTERSON AIR FORCE BASE, OHIO

MAY 15, 1964

F.R. SCHWARTZBERG, S.H. OSGOOD, R.D. KEYS
AND T.F. KIEFER
The enclosed inserts for the Cryogenic Materials Data Handbook are issued as the third semiannual progress report on Air Force Contract AF33(657)-9161. This handbook of data on solid materials at low temperatures was initially prepared under the sponsorship of the Air Force Ballistic Missile Division by personnel of the Cryogenic Engineering Laboratory, National Bureau of Standards, Boulder, Colorado. During the performance of this work, the responsibility for the handbook was transferred to the Aeronautical Systems Division. The eleventh quarterly report, dated 15 February 1962, was the final addition to the handbook prepared by the National Bureau of Standards.

The contract to continue the generation, assimilation, and presentation of data for the handbook was awarded to the Materials Research Section of Martin Company, Denver Division, in June 1962.

The handbook's scope was increased so that additional properties and materials could be included. The index insert page shows the current scope of materials. It appears that some confusion exists regarding the use of the index. The index, pages iii and iv, identifies those materials that have been coded for inclusion in the handbook and the properties desired for those materials. To determine which data are now included in the handbook, refer to the accumulative index, page vi. This index identifies the latest progress report containing data for a specific material and property.

This progress report contains considerable tensile data obtained by Martin Company under the subject contract effort. These data are identified by reference number 1115. Data obtained from other RTD programs, such as General Dynamics/Astronautics work on pressure vessel materials for cryogenic application [Contract AF33(615)-7719] and Narmco's work on the performance of plastic laminates under cryogenic temperatures [Contract AF33(615)-8289], are included. References 1122 and 1124, respectively, identify data from these programs. A number of graphs replotting the original National Bureau of Standards data are also included. Reference 137 identifies this work.

Plans to issue a completely revised handbook in early 1964 have been altered. The revision has been rescheduled to be completed in mid-year. The revised handbook will be issued as a replacement.
for the existing document. All data will be replotted in the new format. All copies of the handbook will be punched for a standard three-hole binder. Obsolete data will be deleted and the reference numbering system will be streamlined. Inserts to keep the new handbook current will still be issued semiannually.

To make the forthcoming handbook as complete as possible, users are urged to submit appropriate data for inclusion in the handbook. Information can be forwarded to the following address:

Fred R. Schwartzberg, Mail No. L-10
Martin Company
P.O. Box 179
Denver, Colorado 80201
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1-15-64
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- Elongation vs. Temperature
- Data for 0.750-in. Dia Bar

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- Reduction of Area vs. Temperature
- Data for 0.750-in. Dia Bar

*Graphs showing elongation and reduction of area of 2020 aluminum at various temperatures.*

*1-15-64*
NOTE: ALL CURVES 76, 0.750-IN. DIA BAR (137)

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IMPACT ENERGY OF 2020 ALUMINUM
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THERMAL EXPANSION OF 2024 ALUMINUM

EXPANSION \( \frac{L_T - L_{68} \times 10^5}{L_{68}} \)

TEMPERATURE (°F)

0 100

0 100

-400 -300 -200 -100 0 100

-500 -400 -300 -200 0 100

1.750-IN. DIA BAR (137)

(1-15-64)
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0.008-IN. SHEET (1106)
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STRESS (10^3 PSI)

TEMPERATURE (°F)

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A.8.p

THERMAL EXPANSION OF 2014 ALUMINUM

EXPANSION \( \frac{(L_T - L_{68})}{L_{68}} \times 10^5 \)

TEMPERATURE (°F)

TS, 0.050-IN. PLATE, LONG. (1115)
NOTE: ALL CURVES (T62 AND T61-0.100-IN. SHEET, T67-0.063-IN. SHEET).

TEMPERATURE (°F)

MODULUS OF ELASTICITY OF 2219 ALUMINUM

MODULUS (10^6 PSI)
MODULUS OF ELASTICITY OF 2219 ALUMINUM

TEMPERATURE (°F)

MODULUS (10^6 PSI)

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PLATE, LONG. (1115)
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\[
\left( \frac{L_T - L_{68}}{L_{68}} \times 10^5 \right)
\]

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NOTE: ALL CURVES TS, NOTCHED.
0.125-IN. SHEET (1115).

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NOTE: ALL CURVES T6,
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TEMPERATURE (°F)

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NOTE: ALL CURVES 45% COLD REDUCED, 0.375 IN. DIA BAR (137).
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MODULUS OF RIGIDITY OF ELGILOY

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THERMAL EXPANSION OF ELGILOY
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B.3.p

EXPANSION

\( \left( \frac{L - L_{68}}{L_{68}} \right) \times 10^5 \)

26% COLD REDUCED,
0.750-1N.
DIA BAR (137)

TEMPERATURE (°F)

-460 -400 -300 -200 -100 0 100

-250 -200 -150 -100 -50 0 50
STRESS-STRAIN DIAGRAM FOR BERYLLIUM COPPER

NOTE: ALL CURVES ANNEALED,
0.750-IN. DIA BAR (137).
STRESS-STRAIN DIAGRAM FOR BERYLLIUM COPPER

NOTE: ALL CURVES SOLUTION TREATED CONDITION, 0.750 - IN. DIA BAR (137)
THERMAL EXPANSION OF 70/30 BRASS
THERMAL EXPANSION OF 17-4 PH STAINLESS STEEL

H 1100, 0.750-IN. DIA BAR (137)
THERMAL EXPANSION OF 17-7PH STAINLESS STEEL

(THERMAL EXPANSION OF 17-7PH STAINLESS STEEL)
NOTE: ALL CURVES SOLUTION TREATED AND AGED
(1800 F/1.5 HR, AC;
1350 F/16 HR, AC),
0.750-IN. DIA BAR

THERMAL EXPANSION OF A-286 STAINLESS STEEL

(1-15-64)
THERMAL EXPANSION OF 302 STAINLESS STEEL

(1-15-64)

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THERMAL EXPANSION OF 303 STAINLESS STEEL
THERMAL EXPANSION OF 304 STAINLESS STEEL
THERMAL EXPANSION OF 310 STAINLESS STEEL

EXPANSION \( \left( \frac{L_T - L_{68}}{L_{68}} \times 10^5 \right) \)

TEMPERATURE (°F)

ANNEALED, 0.750-IN.
DIA BAR (137)

(1-15-64)
THERMAL EXPANSION OF 321 STAINLESS STEEL
THERMAL EXPANSION OF 347 STAINLESS STEEL
THERMAL EXPANSION OF 416 STAINLESS STEEL

(1-15-64)
THERMAL EXPANSION OF 440C STAINLESS STEEL

QUENCHED AND DOUBLE TEMPERED (1870°F/30 MIN,
OQ: 1000°F/6 HR + 1050°F/
6 HR, AQ), 0.750-IN. DIA,
BAR (137)
THERMAL EXPANSION OF 1075 STEEL

(1-15-64)
THERMAL EXPANSION OF 2800
(9% NICKEL) STEEL

DOUBLE NORMALIZED
AND TEMPERED (1650°F, AC;
1450°F, AC; 1050°F/2 HR, AC),
0.750-IN, DIA BAR (137)
THERMAL EXPANSION OF 4340 STEEL

ANNEALED, 0.750-IN.
DIA BAR (137)
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(1-15-64)
E.2.p

NOTE: ALL CURVES SOLUTION TREATED AND AGED
(1300 F/20 HR, AC AGE),
0.750-IN. DIA ROD

TEMPERATURE (°F)

THERMAL EXPANSION OF INCONEL X NICKEL

(1-15-64)
THERMAL EXPANSION OF K MONEL NICKEL
THERMAL EXPANSION OF S MONEL NICKEL

(E.4.p)

ANNEALED, 0.750-IN. DIA BAR (121)
THERMAL EXPANSION OF "A" NICKEL

E.5.p

\[ \frac{L_T - L_{68} \times 10^5}{L_{68}} \]

TEMPERATURE (°F)

-450 -400 -350 -300 -250 -200 -150 -100 -50 0 50

-100 -150 -200 -250 -300

ANNEALED, 0.750-IN. DIA BAR (137)
E.6.a

NOTE: ALL CURVES LONGITUDINAL, SOLUTION TREATED AND AGED (1950°F/30 MIN, AC; 1450°F/16 HR, AC) EXCEPT AS NOTED.

- 0.020-IN. SHEET (1129)
- SOLUTION TREATED (1975°F/4 HR, WQ)
- 0.750-IN. DIA BAR (137)
- SOLUTION TREATED, 0.020-IN. SHEET (1129)

YIELD STRENGTH OF RENE' 41 NICKEL

TEMPERATURE (°F)
STRESS (10^3 PSI)
NOTE: ALL CURVES TRANSVERSE, SOLUTION TREATED AND AGED (1900 F/30 MIN, AC; 1400 F/15 HR, AC) EXCEPT AS NOTED

YIELD STRENGTH OF RENE' 41 NICKEL

(1-15-64)
E.6.b

NOTE: ALL CURVES LONGITUDINAL, SOLUTION TREATED AND AGED (1900 F/30 MIN, AC; 1400 F/16 HR, AC) EXCEPT AS NOTED

SOLUTION TREATED (1975 F/4 HR, WG)
0.780-IN, DIA BAR (137)

0.020-IN, SHEET (1122)

0.020-IN, SHEET (1123)

TENSILE STRENGTH OF RENE' 41 NICKEL

(1-15-64)
TENSILE STRENGTH OF RENE' 41 NICKEL

(1-15-64)
E.6.b-2

NOTCH TENSILE STRENGTH OF RENE' 41 NICKEL

NOTE: ALL CURVES LONGITUDINAL, SOLUTION TREATED AND AGED (1950 F/30 Min, AC; 1400 F/16 HR, AC) EXCEPT AS NOTED
NOTCH STRENGTH RATIO OF RENE' 41 NICKEL

NOTE: ALL CURVES LONGITUDINAL, SOLUTION TREATED AND AGED (1950 F/30 MIN, AC; 1400 F/16 HR, AC) EXCEPT AS NOTED

K = 7.2, 0.020-IN. SHEET (1122)

K = 21, 0.020-IN. SHEET (1122)
NOTCH TENSILE STRENGTH OF RENE' 41 NICKEL

(1-15-64)
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NOTCH STRENGTH RATIO OF RENE’ 41 NICKEL

NOTE: ALL CURVES TRANSVERSE, SOLUTION TREATED AND AGED (1950 F/30 MIN, AC; 1400 F/12 HR, AC) EXCEPT AS NOTED
NOTE: All curves solution treated and aged (950 F/30 min, AC; 1400 F/16 hr, AC), as-TIG welded, no filler, 0.020-in. sheet (1122)

E.6.b-6

WELD TENSILE STRENGTH OF RENE' 41 NICKEL
E.6.c

NOTE: ALL CURVES TRANSVERSE, SOLUTION TREATED AND AGED (1850 F/30 MIN, AC; 1400 F/16 HR, AC) EXCEPT AS NOTED.

SOLUTION TREATED, 0.020-IN. SHEET (1123)

SOLUTION TREATED (1975 F/4 HR, WQ)
0.750-IN. DIA BAR (137)

0.020-IN. SHEET (1122)

0.020-IN. SHEET (1123)

ELONGATION OF RENE' 41 NICKEL
NOTE: ALL CURVES LONGITUDINAL, SOLUTION TREATED AND AGED (1850 F/30 MIN, AC; 1400 F/16 HR, AC) EXCEPT AS NOTED.

Elongation of Rene' 41 Nickel

- Elongation (Percent)
- Temperature (°F)

0.020-in. Sheet (1122)
0.020-in. Sheet (1123)
REDUCTION IN AREA OF RENE' 41 NICKEL
THERMAL EXPANSION OF RENÉ 41 NICKEL

E.6.p

\[
\frac{L - L_{68}}{L_{68}} \times 10^5
\]

TEMPERATURE (°F)

SOLUTION TREATED
(1975°F/4HR, WQ) 0.750-1IN.
DIA BAR (137)
THERMAL EXPANSION OF HASTELLOY B
THERMAL EXPANSION OF D-979 NICKEL

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YIELD STRENGTH OF R-235 NICKEL

NOTE: ALL CURVES SOLUTION TREATED (2150 F/AC), 0.015-IN. SHEET (1124)
TENSILE STRENGTH OF R-235 NICKEL

NOTE: ALL CURVES SOLUTION TREATED (2150 F/AC), 0.015-IN. SHEET (1126)
E.9.b-1

NOTE: ALL CURVES SOLUTION TREATED
(2150 F/AC), 0.015-IN. SHEET (1924)

AGED 1450 F/24 HR. AC

AGED 1600 F/20 MIN. AC

SOLUTION TREATED

NOTCH TENSILE STRENGTH OF R-235 NICKEL
WELD TENSILE STRENGTH OF R-235 NICKEL

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NOTE: ALL CURVES SOLUTION TREATED (2150 F/AC), TIG WELDED, NO FILLER, LONGITUDINAL, 0.015-IN. SHEET (1122)

STRESS ($10^3$ PSI)

TEMPERATURE ($^\circ$F)

POST-AGED 1600 F/20 MIN, AC

POST-AGED 1450 F/24 HR, AC

AS-WELDED

(1-15-64)
E.9c

NOTE: ALL CURVES SOLUTION TREATED (2150 F/AC), 0.013-IN. SHEET (1126)

ELONGATION OF R-235 NICKEL
THERMAL EXPANSION OF 5AL-2.5 SN TITANIUM

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THERMAL EXPANSION OF 6AL-4V TITANIUM
YIELD STRENGTH OF 8AL-1MO-1V TITANIUM
NOTE: ALL CURVES 0.002-IN. SHEET (1118)

TENSILE STRENGTH OF 8AL-1MO-1V TITANIUM
WELD TENSILE STRENGTH OF 8AL-1MO-1V TITANIUM
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ELONGATION OF 8AL-1MO-1V TITANIUM

NOTE: ALL CURVES 0.032-IN. SHEET (1115)
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H.6.b

NOTE: ALL CURVES 181 GLASS CLOTH REINFORCEMENT, 0.125-IN. NOMINAL PANEL THICKNESS (1124)

TENSILE STRENGTH OF EPOXY - FIBERGLASS LAMINATE
COMPRESSIVE STRENGTH OF EPOXY - FIBERGLASS LAMINATE
FATIGUE STRENGTH OF EPOXY-FIBERGLAS LAMINATE

NOTE: ALL CURVES EPOXY RESIN/MI GLASS CLOTH REINFORCEMENT, 32.8-40.5% RESIN CONTENT, 0.125 IN. NOMINAL PANEL THICKNESS, AXIAL LOAD, R = 0.85 (112A).
FATIGUE STRENGTH OF EPOXY-FIBERGLAS LAMINATE

NOTE: ALL CURVES EPON 1001 RESIN/911 GLASS CLOTH REINFORCEMENT, 34.8 = 38.2% RESIN CONTENT, 0.125-IN. NOMINAL PANEL THICKNESS, AXIAL LOAD, R = 0.05 (1124).
NOTE: ALL CURVES 181 GLASS CLOTH REINFORCEMENT, 0.125-IN. NOMINAL PANEL THICKNESS (1124)

FLEXURAL STRENGTH OF EPOXY - FIBERGLAS LAMINATE

1-15-64
H.7.b

NOTE: ALL CURVES 181 GLASS CLOTH REINFORCEMENT, 9.125-IN. NOMINAL PANEL THICKNESS (1/24)

TENSILE STRENGTH OF PHENOLIC FIBERGLAS LAMINATE

TEMPERATURE (°F)

STRESS (10^3 PSI)

NARMCO 806 RESIN, 27.2–34.4 % RESIN CONTENT

CTL 91 LD RESIN, 22.6–28.5 % RESIN CONTENT

1-15-64
H.7.j

COMPRESSION STRENGTH OF PHENOLIC - FIBERGLASS LAMINATE

NOTE: ALL CURVES 161 GLASS CLOTH REINFORCEMENT, 0.250-IN. NOMINAL PANEL THICKNESS (1/2 IN.)
Fatigue strength of Phenolic-Fiberglass laminate

NOTE: All curves CTL 91 LC Resin/91 Glass
Cloth reinforcement, 22.2 - 23.3% resin
Content, 0.135 - in. nominal panel thickness
Neck, axial load, R = 0.95 (114).
NOTE: ALL CURVES 181 GLASS CLOTH REINFORCEMENT, 5.125-IN. NOMINAL PANEL THICKNESS (1124)

FLEXURAL STRENGTH OF PHENOLIC - FIBERGLAS LAMINATE

1-15-64
NOTE: ALL CURVES 181 GLASS CLOTH REINFORCEMENT, 0.125-IN. NOMINAL PANEL THICKNESS (1/8"

TENSILE STRENGTH OF POLYESTER - FIBERGLAS LAMINATE
NOTE: ALL CURVES 181 GLASS CLOTH REINFORCEMENT, 0.800-IN. NOMINAL PANEL THICKNESS (1124)

COMPRESSIVE STRENGTH OF POLYESTER - FIBERGLAS LAMINATE
FLEXURAL STRENGTH OF POLYESTER - FIBERGLASS LAMINATE

H.8.x

NOTE: ALL CURVES 161 GLASS CLOTH REINFORCEMENT, 0.125-IN. NOMINAL PANEL THICKNESS (1/16)

- HEETRON 92 RESIN, 42.6-55.4% RESIN CONTENT
- PARAPLEX P43 RESIN, 34.5-42.6% RESIN CONTENT
NOTE: ALL CURVES 101 GLASS CLOTH REINFORCEMENT, 0.125-IN. NOMINAL PANEL THICKNESS (1/8"

LAMINAC 4232 RESIN, 31.5-46.1\% RESIN CONTENT

VIBRIN 135 RESIN, 32.4-35.4\% RESIN CONTENT

TENSILE STRENGTH OF HIGH TEMPERATURE POLYESTER - FIBERGLAS LAMINATE
NOTE: ALL CURVES IS1 GLASS CLOTH REINFORCEMENT,
0.500-IN. NOMINAL PANEL THICKNESS (1124)

COMPRRESSIVE STRENGTH OF HIGH TEMPERATURE POLYESTER - FIBERGLAS LAMINATE
FATIGUE STRENGTH OF HIGH TEMPERATURE POLYESTER-FIBERGLAS LAMINATE

NOTE: ALL CURVES VIBRIN 135 RESIN/H1 GLASS CLOTH REINFORCEMENT, 31.4-34.6% RESIN CONTENT, 0.125-IN. NOMINAL PANEL THICKNESS, AXIAL LOAD, R = 0.98 (1120).
NOTE: ALL CURVES 181 CLOTH REINFORCEMENT, 0.125-IN., NOMINAL PANEL THICKNESS (1/8")

FLEXURAL STRENGTH OF HIGH TEMPERATURE POLYESTER - FIBERGLASS LAMINATE

TEMPERATURE (°F)

STRESS (10^3 PSI)

VIBRIN 135 RESIN, 32.4-33.4% RESIN CONTENT

LAMINAL 423X RESIN, 31.3-46.1% RESIN CONTENT

1-15-64
NOTE: ALL CURVES 161 GLASS CLOTH REINFORCEMENT, 0.125-IN. NOMINAL PANEL THICKNESS (1124)

TENSILE STRENGTH OF SILICONE - FIBERGLAS LAMINATE

H.10.b
NOTE: ALL CURVES 181 GLASS CLOTH REINFORCEMENT, 0.005-IN. NOMINAL PANEL THICKNESS (112A)

COMPRESSION STRENGTH OF SILICONE – FIBERGLASS LAMINATE
Fatigue Strength of Silicone-Fiberglass Laminate

Note: All curves marmed 513 resin/181 glass cloth reinforcement, 35.5% resin content, 0.132-in. nominal panel thickness, axial load, N = 0.18 (122).
FATIGUE STRENGTH OF SILICONE-FIBERGLAS LAMINATE

NOTE: ALL CURVES TREVANO P-130 RESIN/181 GLASS CLOTH REINFORCEMENT, 30-32% RESIN CONTENT, 0.125-IN. NOMINAL PANEL THICKNESS, AXIAL LOAD, R = 0.95 (1154).
FLEXURAL STRENGTH OF SILICONE - FIBERGLAS LAMINATE


